



US009435669B2

(12) **United States Patent**
Boyd et al.

(10) **Patent No.:** **US 9,435,669 B2**
(45) **Date of Patent:** **Sep. 6, 2016**

(54) **INTAKE GAS SENSOR WITH VORTEX FOR INTERNAL COMBUSTION ENGINE**

(71) Applicant: **Robert Bosch GmbH**, Stuttgart (DE)

(72) Inventors: **David Boyd**, Greenville, SC (US);
Craig Magera, Simpsonville, SC (US)

(73) Assignee: **Robert Bosch GmbH**, Stuttgart (DE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 283 days.

5,012,670 A *	5/1991	Kato et al.	73/31.05
5,942,092 A *	8/1999	Weyl et al.	204/424
7,032,446 B2	4/2006	Nakada et al.	
7,493,796 B2 *	2/2009	Wilde	73/23.31
8,001,827 B2 *	8/2011	Weyl et al.	73/23.31
8,584,504 B2 *	11/2013	Ito et al.	73/23.2
2002/0095916 A1	7/2002	Turner et al.	
2003/0046996 A1 *	3/2003	Nakada et al.	73/202.5
2004/0025481 A1	2/2004	Bugli et al.	
2005/0178187 A1 *	8/2005	Nakagawa	73/31.05
2005/0241937 A1 *	11/2005	Shichida et al.	204/424
2008/0016946 A1 *	1/2008	Thanigachalam et al. ..	73/31.05
2008/0016948 A1 *	1/2008	Yamada	73/31.05

(Continued)

(21) Appl. No.: **13/793,129**

(22) Filed: **Mar. 11, 2013**

(65) **Prior Publication Data**

US 2014/0174176 A1 Jun. 26, 2014

Related U.S. Application Data

(60) Provisional application No. 61/739,954, filed on Dec. 20, 2012.

(51) **Int. Cl.**

G01D 11/24 (2006.01)

G01N 27/407 (2006.01)

(52) **U.S. Cl.**

CPC **G01D 11/24** (2013.01); **G01N 27/4077** (2013.01)

(58) **Field of Classification Search**

CPC . G01D 11/24; G01D 11/245; G01N 27/4077
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,326,862 A	4/1982	Suzuki	
4,507,192 A *	3/1985	Ebizawa et al.	204/428
4,916,934 A *	4/1990	Nagata et al.	73/31.05

FOREIGN PATENT DOCUMENTS

JP	2001099807	4/2001
JP	2003161717	6/2003

OTHER PUBLICATIONS

International Search Report and Written Opinion for Application No. PCT/US2013/075327 dated Apr. 2, 2014 (11 pages).

Primary Examiner — Peter Macchiarolo

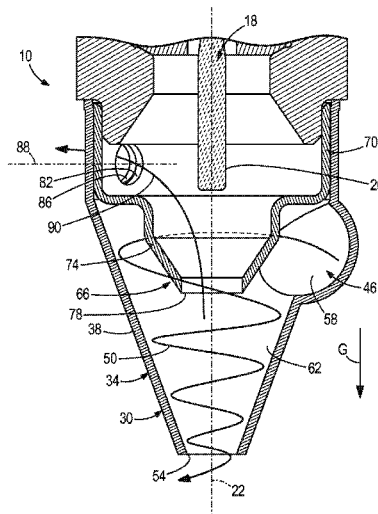
Assistant Examiner — Natalie Huls

(74) *Attorney, Agent, or Firm* — Michael Best & Friedrich, LLP

(57) **ABSTRACT**

A gas sensor includes a sensor housing and a sensing element located within the sensor housing. The sensing element defines an axis. The sensing element has a distal end extending from the sensor housing. The gas sensor further includes a sensor protection element coupled to the sensor housing and at least partially surrounding the distal end of the sensing element. The sensor protection element includes a tube having a conical portion, and a gas inlet located on the tube, the gas inlet spaced from the axis. The gas inlet is shaped to direct gas into the tube to induce a vortex gas flow within the conical portion of the tube.

20 Claims, 5 Drawing Sheets



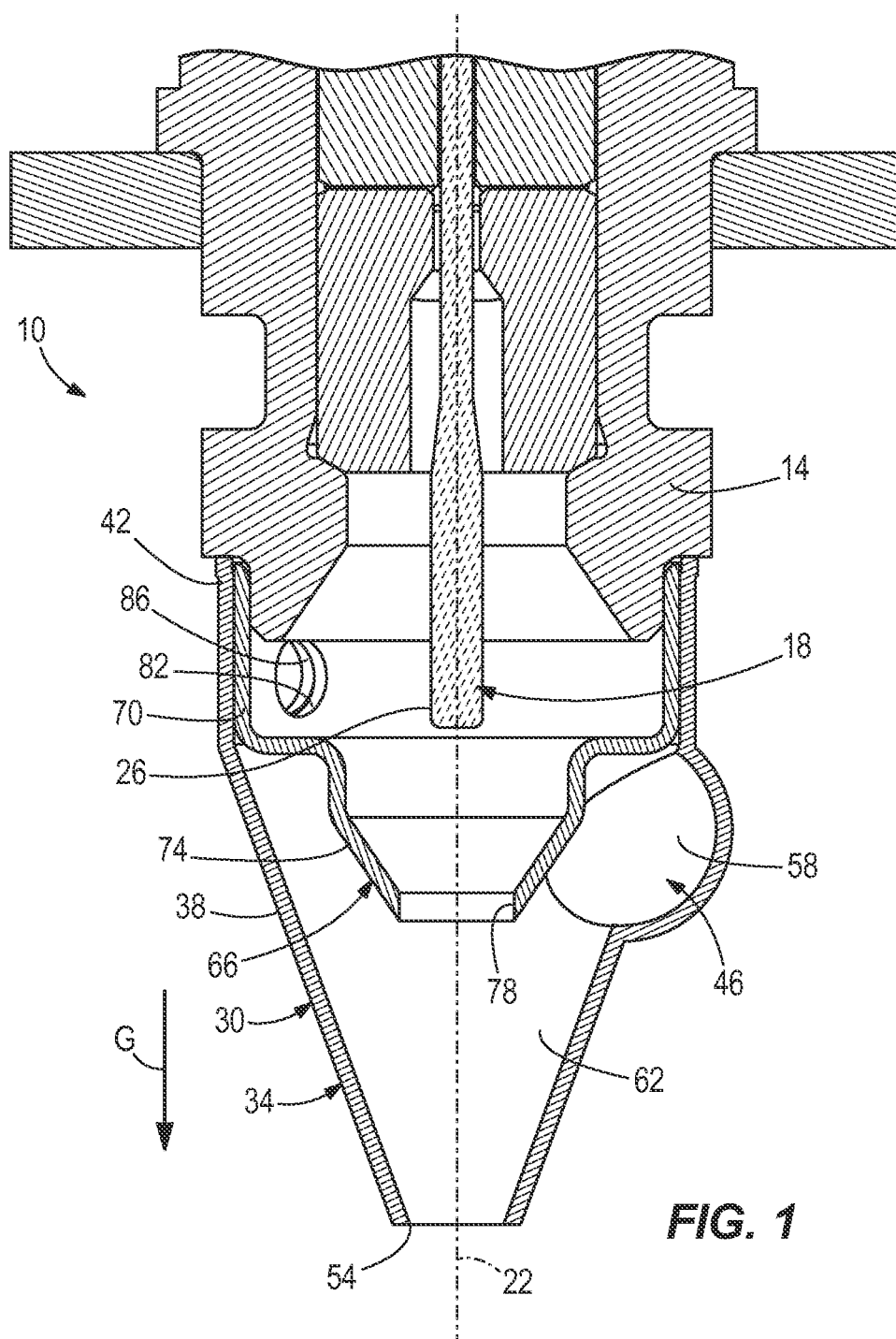
(56)

References Cited

U.S. PATENT DOCUMENTS

2008/0073209	A1 *	3/2008	Yamada	204/424	2009/0166358	A1	7/2009	Bose	
2008/0086989	A1	4/2008	Sheidler		2010/0024524	A1 *	2/2010	Ebner et al.	73/31.05
2008/0105037	A1 *	5/2008	Nakashima et al.	73/31.05	2010/0288230	A1	11/2010	McCauley et al.	
2008/0156301	A1	7/2008	Rockwell et al.		2011/0114070	A1	5/2011	Liu et al.	
2008/0277282	A1 *	11/2008	Kume et al.	204/424	2011/0209523	A1 *	9/2011	Otsubo et al.	73/23.31
2009/0100907	A1 *	4/2009	Mizutani et al.	73/31.05	2012/0111092	A1 *	5/2012	Nakashima	73/23.31
2009/0117007	A1 *	5/2009	Furuta et al.	422/83	2012/0145543	A1 *	6/2012	Sugaya et al.	204/424
					2013/0305809	A1 *	11/2013	Fujita et al.	73/31.05
					2014/0298931	A1 *	10/2014	Oba et al.	73/866.5
					2014/0299469	A1 *	10/2014	Oba et al.	204/412

* cited by examiner



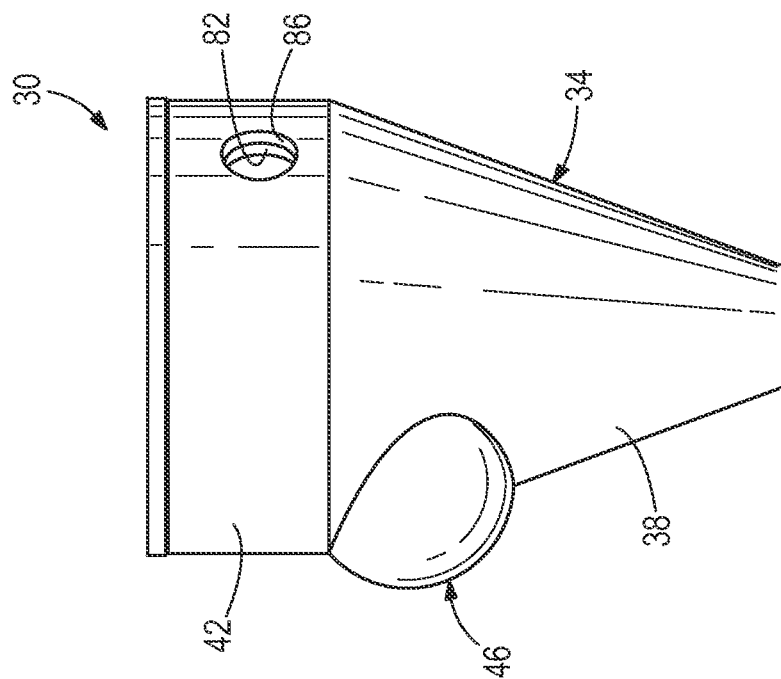


FIG. 3

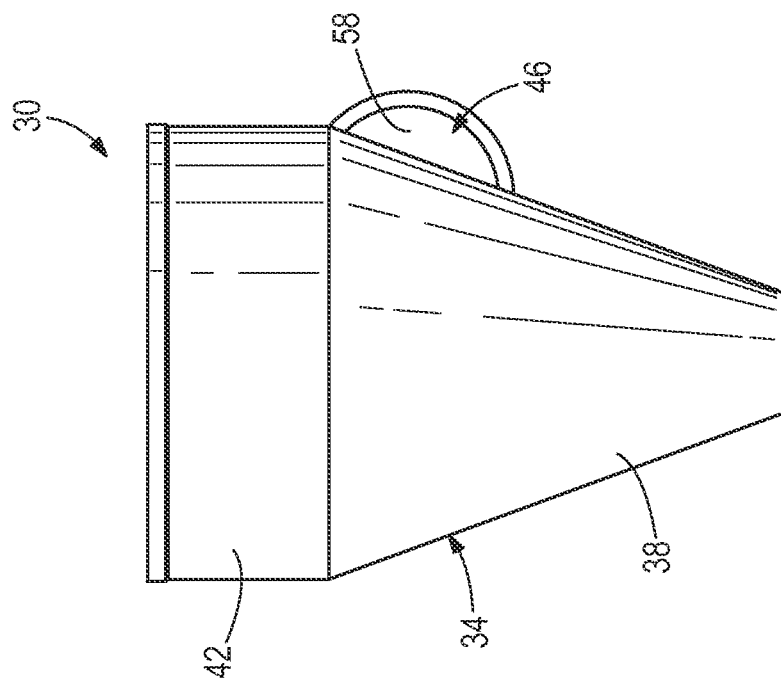
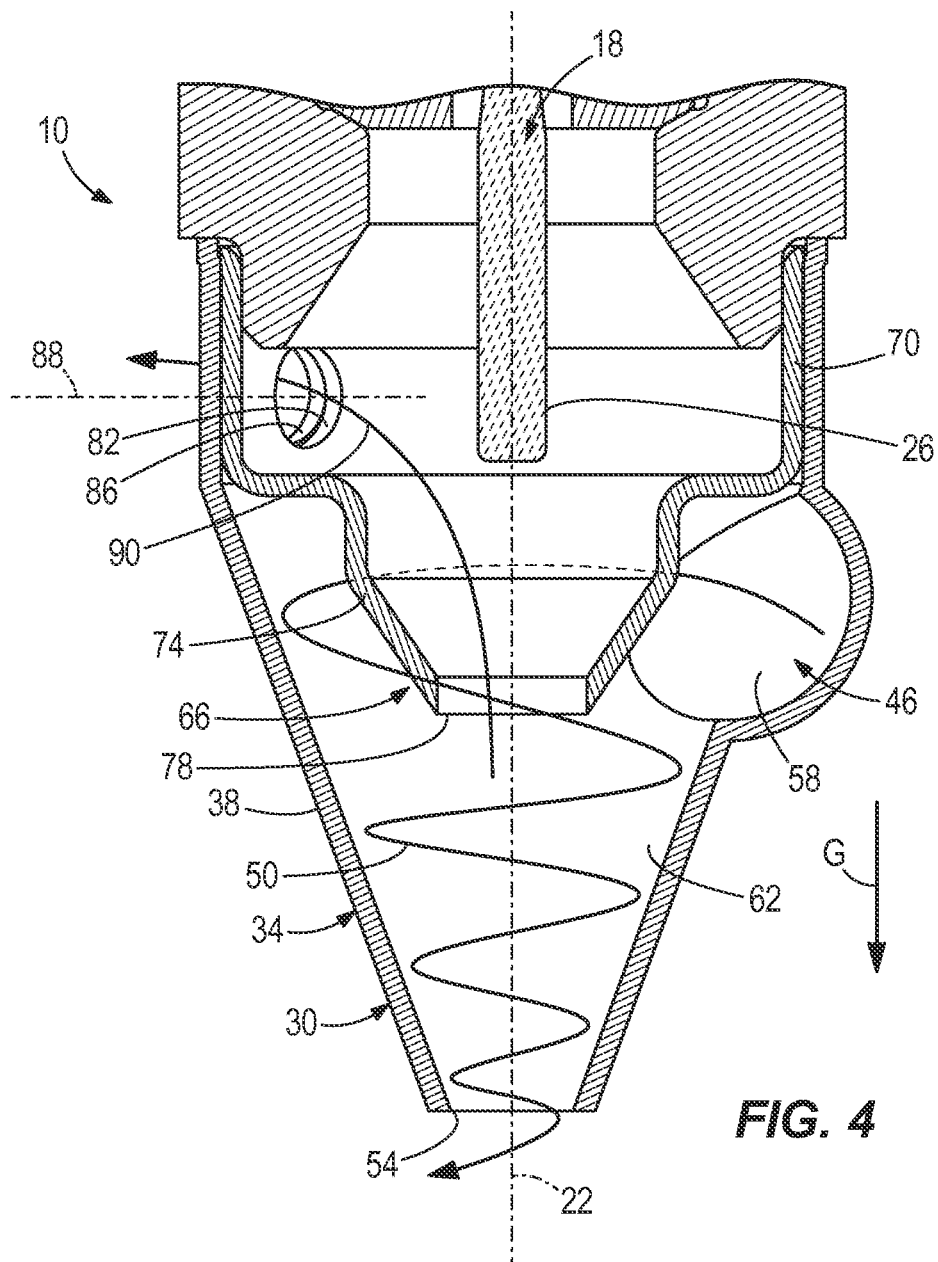


FIG. 2



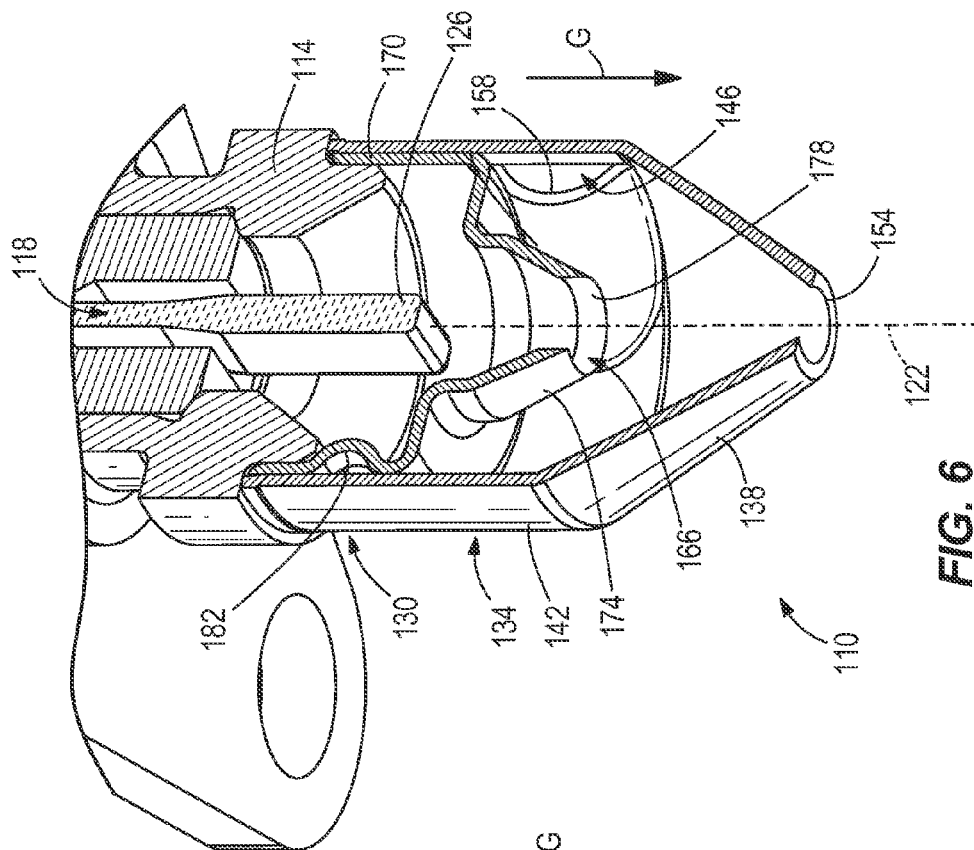


FIG. 5

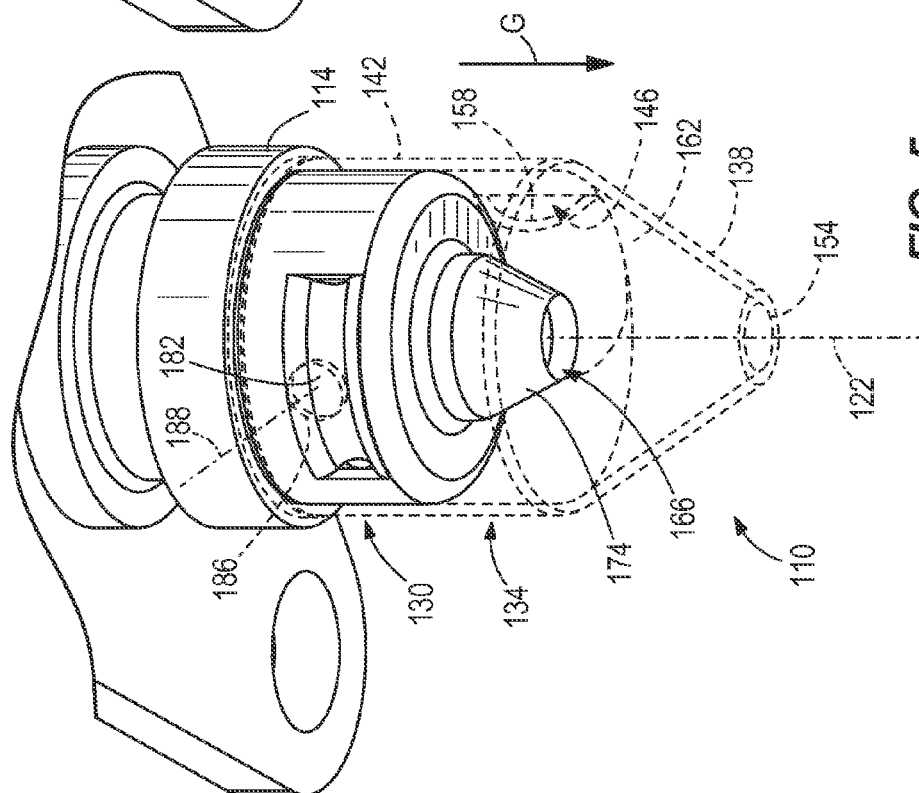


FIG. 6

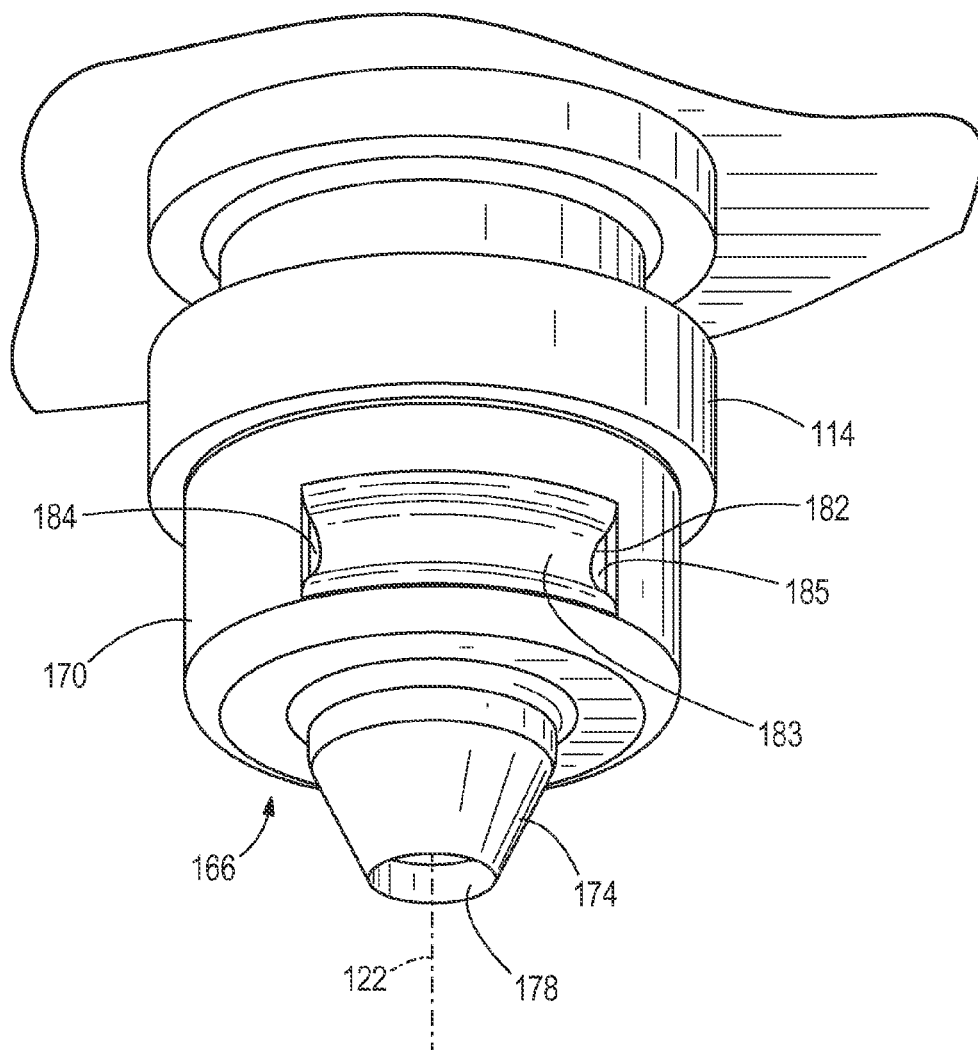


FIG. 7

1

INTAKE GAS SENSOR WITH VORTEX FOR INTERNAL COMBUSTION ENGINE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application No. 61/739,954, filed Dec. 20, 2012, the entire contents of which are incorporated herein by reference.

BACKGROUND

The present invention relates to a gas (e.g., oxygen) sensor, and more particularly to a gas sensor with a sensor protection element for use in low temperature environments.

The use of gas sensors to monitor oxygen levels in an internal combustion engine is known. Current gas sensors are designed for high temperature areas in the engine, such as an exhaust manifold, where the exhaust gas can reach temperatures as high as 1030 degrees Celsius. The gas sensors include sensing elements extending from sensor housings for detecting the oxygen levels of the exhaust gas.

Significant amounts of water, particles, and/or other contaminants that may damage a sensing element are not typically present in the exhaust manifolds during operation of the engine, due at least in part to the high temperatures already present in these areas. However, other areas of the engine, including the intake manifold, have significantly lower temperatures than the exhaust manifold. For example, in the intake manifold, temperatures may only reach 130 degrees Celsius. In these lower temperature areas, higher amounts of water, particles, and other contaminants are typically present, as compared with the exhaust manifold. Such water, particles, and/or other contaminants can damage and/or disrupt the sensing element. It would be advantageous therefore to have a gas sensor for use in these low temperature environments that eliminates or removes water, particles, and/or other contaminants from the gas sensor, so that the sensing element remains protected.

SUMMARY

In accordance with one construction, the invention provides a gas sensor including a sensor housing and a sensing element located within the sensor housing. The sensing element defines an axis. The sensing element has a distal end extending from the sensor housing. The gas sensor further includes a sensor protection element coupled to the sensor housing and at least partially surrounding the distal end of the sensing element. The sensor protection element includes a tube having a conical portion, and a gas inlet located on the tube, the gas inlet spaced from the axis. The gas inlet is shaped to direct gas into the tube to induce a vortex gas flow within the conical portion of the tube.

In accordance with another construction, the invention provides a gas sensor including a sensor housing and a sensing element located within the sensor housing. The sensing element defines an axis. The sensing element has a distal end extending from the sensor housing. The gas sensor further includes a sensor protection element coupled to the sensor housing and at least partially surrounding the distal end of the sensing element. The sensor protection element includes an outer tube having a conical portion. A first gas inlet is located on the outer tube. The first gas inlet is spaced from the axis. The sensor protection element further includes a waste outlet located on the conical portion. The axis extends through the waste outlet. The sensor protection

2

element further includes an inner tube disposed within the outer tube. The sensing element is located within the inner tube. The sensor protection element further includes a second gas inlet located on the inner tube. The axis extends through the second gas inlet. The sensor protection element further includes a first gas outlet located on the inner tube. The first gas outlet is spaced from the axis. The sensor protection element further includes a second gas outlet located on the outer tube. The second gas outlet is spaced from the axis.

Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front, cross-sectional view of a gas sensor according to one construction of the invention, the gas sensor including a sensor protection element.

FIG. 2 is a front view of the sensor protection element of FIG. 1.

FIG. 3 is a rear view of the sensor protection element of FIG. 1.

FIG. 4 is a front, cross-sectional view of the gas sensor of FIG. 1, illustrating a gas flow within the gas sensor protection element.

FIG. 5 is a broken-away, perspective view of a gas sensor according to another construction of the invention.

FIG. 6 is a perspective cross-sectional view of the gas sensor of FIG. 5, including an inner tube.

FIG. 7 is a perspective view of the inner tube of FIG. 6.

DETAILED DESCRIPTION

Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways.

FIGS. 1-4 illustrate a gas sensor 10. The gas sensor 10 includes a sensor housing 14, and a sensing element 18 located within the sensor housing 14. The sensing element 18 is an oxygen sensing element, although other types of sensing elements 18 are also possible. The sensing element 18 defines an axis 22. The sensing element 18 has a distal end 26 extending from the sensor housing 14. The distal end 26 extends along the axis 22.

The gas sensor 10 further includes a sensor protection element 30. The sensor protection element 30 is coupled to the sensor housing 14. Specifically, the sensor protection element 30 is coupled to the sensor housing 14 via a frictional fit over the housing 14, although other forms of coupling are also possible, including attachment with fasteners, brazing, welding, etc. The sensor protection element 30 at least partially surrounds the distal end 26 of the sensing element 18. The sensor protection element 30 controls the flow of gas from outside the gas sensor protection element 30, into communication with the sensing element 18, and back outside the sensor protection element 30.

The sensor protection element 30 includes an outer tube 34 having a conical portion 38 and a cylindrical portion 42. A gas inlet 46 is located on the conical portion 38. The gas inlet 46 is spaced from the axis 22. The gas inlet 46 is configured to direct gas into the conical portion 38. With reference to FIG. 4, the gas inlet 46 is configured to direct

3

gas into the conical portion 38 at an angle such that at least a portion of the gas generates into a swirling vortex 50 within the conical portion 38. The gas entering through gas inlet 46 includes water, particles, and/or other contaminants. With the aid of gravity (illustrated as arrow "G" in FIGS. 1 and 4), the swirling vortex 50 forces the water, particles, and/or other contaminants in the gas toward a waste outlet 54, and inhibits the water, particles, and/or other contaminants from reaching the sensing element 18. The waste outlet 54 is located on the conical portion 38. The axis 22 extends through the waste outlet 54.

The gas inlet 46 illustrated in FIGS. 1-4 has an outwardly facing scoop structure. The outwardly facing scoop structure extends away from the axis 22. The outwardly facing scoop structure includes an inner concave surface 58. Gas entering the gas inlet 46 moves along the inner concave surface 58 until the gas is within the conical portion 38. The conical portion 38 includes an inner surface 62. The gas entering the gas inlet 46 is directed along the inner concave surface 58, and then further along the inner surface 62. The gas inlet 46 directs gas into the conical portion 38 generally tangentially to the inner surface 62.

With continued reference to FIGS. 1-4, the sensor protection element 30 further includes an inner tube 66. The inner tube 66 is disposed within the outer tube 34. The sensing element 18 is located within the inner tube 66. Specifically, the distal end 26 of the sensing element 18 is located within the inner tube 66. The vortex 50 occurs between the outer tube 34 and inner tube 66.

The inner tube 66 includes a cylindrical portion 70, and a conical portion 74. A gas inlet 78 is located on the conical portion 74 of the inner tube 66. The axis 22 extends through the gas inlet 78. The gas inlet 78 is located generally at or below the gas inlet 46 (the terms "below" and "downward" refer to a direction along axis 22 signified by gravity arrow "G" in FIGS. 1 and 4), such that any gas that enters through gas inlet 46 must divert downward first prior to entering upward through gas inlet 78. This arrangement of the gas inlets 46, 78 creates a tortuous pathway for gas to reach sensing element 18, and further inhibits water, particles, and/or other contaminants from reaching the sensing element 18.

With continued reference to FIGS. 1-4, the inner tube 66 includes a gas outlet 82. The gas outlet 82 is spaced from the axis 22. The gas outlet 82 is located on the cylindrical portion 70 of the inner tube 66. The gas outlet 82 is disposed on a substantially opposite side of the gas sensor protection element 30 as the gas inlet 46.

The outer tube 34 further includes a gas outlet 86. The gas outlet 86 is spaced from the axis 22. The gas outlet 86 is located on the cylindrical portion 42 of the outer tube 34. The gas outlet 86 is aligned with the gas outlet 82 along an axis 88 that extends perpendicular to axis 22, such that gas within the inner tube 66 is able to move directly from within the inner tube 66 out through the outer tube 34. In the illustrated construction, the gas outlets 82, 86 have the same diameter, although other shapes and configurations for gas outlets 82, 86 are also possible.

As illustrated in FIG. 4, the gas inlet 46 admits and directs gas into the outer tube 34 in a tangential direction to induce the vortex flow 50. Water, particles, and/or other contaminants are driven to the inner wall surface 62 of the outer tube 34 by centrifugal force, and ultimately out through the waste outlet 54. This arrangement inhibits water, particles, and/or other contaminants from reaching the sensing element 18. Thus, only clean gas, denoted by line 90, is admitted into the inner tube 66 through the gas inlet 78. Once the clean gas 90

4

flows past the sensing element 18, the clean gas 90 exits the gas sensor protection element 30 through the gas outlets 82, 86. Negative pressure is developed by the gas outlets 82, 86, thereby facilitating the gas flow illustrated in FIG. 4.

FIGS. 5-7 illustrate a gas sensor 110 in accordance with another construction. The gas sensor 110 includes a sensor housing 114, and a sensing element 118 located within the sensor housing 114. The sensing element 118 is an oxygen sensing element, although other types of sensing elements 118 are also possible. The sensing element 118 defines an axis 122. The sensing element 118 has a distal end 126 extending from the sensor housing 114. The distal end 126 extends along the axis 122.

The gas sensor 110 further includes a sensor protection element 130. The sensor protection element 130 is coupled to the sensor housing 114. Specifically, the gas sensor protection element 130 is coupled to the sensor housing 114 via a frictional fit over the housing 114, although other forms of coupling are also possible, including attachment with fasteners, brazing, welding, etc. The sensor protection element 130 at least partially surrounds the distal end 126 of the sensing element 118. The sensor protection element 130 controls the flow of gas from outside the sensor protection element 130, into communication with the sensing element 118, and back outside the sensor protection element 130.

The sensor protection element 130 includes an outer tube 134 having a conical portion 138 and a cylindrical portion 142. A gas inlet 146 is located on the cylindrical portion 142. The gas inlet 146 is spaced from the axis 122. The gas inlet 146 is configured to direct gas into the conical portion 138. In particular, the gas inlet 146 is configured to direct gas into the conical portion 138 at an angle such that at least a portion of the gas generates into a swirling vortex within the conical portion 138 (similar to vortex 50 in FIG. 4). The gas entering through gas inlet 146 includes water, particles, and/or other contaminants. With the aid of gravity, the swirling vortex forces the water, particles, and/or other contaminants in the gas toward a waste outlet 154, and inhibits the water, particles, and/or other contaminants from reaching the sensing element 118. The waste outlet 154 is located on the conical portion 138. The axis 122 extends through the waste outlet 154.

The gas inlet 146 illustrated in FIGS. 5-7 has an inwardly facing scoop structure. The inwardly facing scoop structure includes an outer concave surface 158. Gas entering the gas inlet 146 moves along the outer concave surface 158 until the gas is within the conical portion 138. The inwardly facing scoop structure extends toward the axis 122. Gas entering the gas inlet 146 moves along the gas inlet 146 until the gas is within the conical portion 138. The conical portion 138 includes an inner surface 162. The gas entering the gas inlet 146 is directed along the gas inlet 146, and then further along the inner surface 162. The gas inlet 146 directs gas into the conical portion 138 generally tangentially to the inner surface 162.

With continued reference to FIGS. 5-7, the sensor protection element 130 further includes an inner tube 166. The inner tube 166 is disposed within the outer tube 134. The sensing element 118 is located within the inner tube 166. Specifically, the distal end 126 of the sensing element 118 is located within the inner tube 166.

As illustrated in FIG. 6, the inner tube 166 includes a cylindrical portion 170, and a conical portion 174. A gas inlet 178 is located on the conical portion 174 of the inner tube 166. The axis 122 extends through the gas inlet 178. The gas inlet 178 is located generally at or below the gas inlet 146 (the terms "below" and "downward" refer to a

5

direction along axis **22** signified by gravity arrow “G” in FIG. **6**), such that any gas that enters through gas inlet **146** must divert downward first prior to entering upward through gas inlet **178**. This arrangement of the gas inlets **146**, **178** creates a tortuous pathway for gas to reach sensing element **118**, and further inhibits water, particles, and/or other contaminants from reaching the sensing element **118**.

With continued reference to FIGS. **5-7**, the inner tube **166** includes a gas outlet **182**. The gas outlet **182** is spaced from the axis **122**. The gas outlet **182** is located on the cylindrical portion **170** of the inner tube **166**. The gas outlet **182** is disposed on a substantially opposite side of the gas sensor protection element **130** as the gas inlet **146**. As illustrated in FIG. **7**, the gas outlet **182** is formed as an indented channel **183** along the cylindrical portion **170**, with two openings **184**, **185** on ends of the indented channel **183**. The gas outlet **182** has an elongate structure. The gas outlet **182** extends generally circumferentially along the cylindrical portion **170**, about the axis **122**.

With reference to FIG. **5**, the outer tube **134** further includes a gas outlet **186**. The gas outlet **186** is spaced from the axis **122**. The gas outlet **186** is located on the cylindrical portion **142** of the outer tube **134** along an axis **188** that extends perpendicular to axis **122**. The gas outlet **186** is spaced from and not aligned with the openings **184**, **185** of the gas outlet **182** along the axis **188**, such that gas within the inner tube **134** must move indirectly from within the inner tube **166** out through the outer tube **134** along a tortuous pathway. This tortuous pathway inhibits water, particles, and/or other contaminants from easily entering the sensor protection element **130** through the gas outlets **182**, **186** and contacting the sensing element **118**. In the illustrated construction, gas outlet **186** has a circular shape, and gas outlet **182** has an indented channel shape, though other shapes are also possible.

With continued reference to FIGS. **5-7**, the gas inlet **146** admits and directs gas into the outer tube **134** in a tangential direction to induce a vortex flow (similar to vortex flow **50** in FIG. **4**). Water, particles, and/or other contaminants are driven to the inner wall surface **162** of the outer tube **134** by centrifugal force, and ultimately out through the waste outlet **154**. This arrangement inhibits water, particles, and/or other contaminants from reaching the sensing element **118**. Thus, only clean gas is admitted into the inner tube **166** through the gas inlet **178**. Once the clean gas flows past the sensing element **118**, the clean gas exits the sensor protection element **130** through the gas outlets **182**, **186**. Negative pressure is developed by the gas outlets **182**, **186**, thereby facilitating the movement of gas flow through the sensor protection element **130**.

Additional variations and modifications of the gas sensor protection elements **30**, **130** are also possible. For example, in some constructions the sensor protection element **30** includes a gas inlet with an inwardly facing scoop structure (similar to gas inlet **146**) located along the conical portion **38** of outer tube **34**, rather than the outwardly facing scoop structure of gas inlet **46**.

In some constructions the sensor protection element **30** includes non-aligned gas outlets (similar to gas outlets **182**, **186**) located on the cylindrical portions **70**, **42**, rather than the directly aligned gas outlets **82**, **86**.

In some constructions the sensor protection element **130** includes a gas inlet with an outwardly facing scoop structure (similar to gas inlet **46**) located on the cylindrical portion **142**, rather than the inwardly facing scoop structure of gas inlet **146**.

6

In some constructions the sensor protection element **130** includes directly aligned gas outlets (similar to gas outlets **82**, **86**) located on the cylindrical portions **170**, **142**, rather than the non-aligned gas outlets **182**, **186**.

Various features and advantages of the invention are set forth in the following claims.

What is claimed is:

1. A gas sensor comprising:

a sensor housing;

a sensing element located within the sensor housing, the sensing element defining a first axis and having a distal end extending from the sensor housing; and

a sensor protection element coupled to the sensor housing and at least partially surrounding the distal end of the sensing element, the sensor protection element including:

an outer tube having a first conical portion, the first conical portion having an inner surface, the outer tube further having a gas inlet, the gas inlet spaced from the first axis, the gas inlet shaped to direct gas into the outer tube to induce a vortex gas flow within the first conical portion of the outer tube, wherein the gas inlet is shaped as one of an outwardly facing scoop structure having an inner concave surface or an inwardly facing scoop structure having an outer concave surface, wherein the gas inlet is configured to direct gas into the first conical portion generally tangentially to the inner surface of the first conical portion, and wherein the outer tube further includes a first gas outlet; and

an inner tube disposed within the outer tube, wherein the inner tube has a second conical portion that tapers in diameter along the first axis, such that the second conical portion has a diameter that decreases along a direction moving away from the sensing element along the first axis.

2. The gas sensor of claim **1**, wherein the gas inlet is on the first conical portion.

3. The gas sensor of claim **1**, wherein the sensor protection element further includes a waste outlet located on the first conical portion.

4. The gas sensor of claim **3**, wherein the first axis extends through the waste outlet.

5. The gas sensor of claim **1**, wherein the outer tube further includes a cylindrical portion.

6. The gas sensor of claim **5**, wherein the gas inlet is on the cylindrical portion.

7. The gas sensor of claim **5**, wherein the first gas outlet is located on the cylindrical portion.

8. The gas sensor of claim **1**, wherein the distal end of the sensing element is located within the inner tube.

9. The gas sensor of claim **1**, wherein the gas inlet is a first gas inlet, and the gas sensor protection element further includes a second gas inlet located on the inner tube at a distal end of the second conical portion.

10. The gas sensor of claim **9**, wherein the first axis extends through the second gas inlet.

11. The gas sensor of claim **1**, wherein the inner tube includes a second gas outlet spaced from the first axis, wherein a second axis extends through at least a portion of both the first gas outlet and the second gas outlet, the second axis extending perpendicular to the first axis.

12. A gas sensor comprising:

a sensor housing;

a sensing element located within the sensor housing, the sensing element defining a first axis and having a distal end extending from the sensor housing; and

7

a sensor protection element coupled to the sensor housing and at least partially surrounding the distal end of the sensing element, the sensor protection element including:

an outer tube having a conical portion;
 a first gas inlet located on the outer tube, the first gas inlet spaced from the first axis;
 a waste outlet located on the conical portion, the first axis extending through the waste outlet;
 an inner tube disposed within the outer tube, the sensing element located within the inner tube;
 a second gas inlet located on the inner tube, the first axis extending through the second gas inlet;
 a first gas outlet located on the inner tube, the first gas outlet spaced from the first axis; and
 a second gas outlet located on the outer tube, the second gas outlet spaced from the first axis, such that a portion of the gas entering the first gas inlet is configured to pass out the waste outlet without passing through the second gas inlet,

wherein a second axis extends perpendicular to the first axis, the second axis extending through the second gas outlet, and wherein the first gas outlet includes an indented channel defined by a radially inwardly extending indentation of the inner tube, wherein the first gas outlet includes openings on opposite ends of the indented channel, the openings spaced from the second axis and also spaced circumferentially from one another along the inner tube.

13. The gas sensor of claim **12**, wherein the second axis extends through at least a portion of both the first gas outlet and second gas outlet.

14. The gas sensor of claim **12**, wherein the first gas inlet is shaped to direct gas into the outer tube to induce a vortex gas flow between the outer tube and the inner tube.

15. The gas sensor arrangement of claim **14**, wherein the outer tube includes a cylindrical portion, and wherein the first gas inlet is shaped as one of an outwardly facing scoop structure and an inwardly facing scoop structure on the cylindrical portion.

8

16. The gas sensor arrangement of claim **14**, wherein the first gas inlet is shaped as one of an inwardly facing scoop structure and an outwardly facing scoop structure on the conical portion.

17. A gas sensor comprising:

a sensor housing;
 a sensing element located within the sensor housing, the sensing element defining a first axis and having a distal end extending from the sensor housing; and
 a sensor protection element coupled to the sensor housing and at least partially surrounding the distal end of the sensing element, the sensor protection element including:

an outer tube having a first conical portion, the first conical portion having an inner surface, the outer tube further having a gas inlet, the gas inlet spaced from the first axis, the gas inlet shaped to direct gas into the outer tube to induce a vortex gas flow within the first conical portion of the outer tube, wherein the gas inlet is shaped as one of an outwardly facing scoop structure having an inner concave surface or an inwardly facing scoop structure having an outer concave surface, wherein the gas inlet is configured to direct gas into the first conical portion generally tangentially to the inner surface of the first conical portion, and wherein the outer tube further includes a first gas outlet; and

an inner tube disposed within the outer tube, wherein the inner tube has a second conical portion, wherein the inner tube includes a second gas outlet spaced from the first axis, wherein a second axis extends through at least a portion of both the first gas outlet and the second gas outlet, the second axis extending perpendicular to the first axis.

18. The gas sensor arrangement of claim **17**, wherein the outer tube includes a cylindrical portion.

19. The gas sensor arrangement of claim **17**, wherein the sensor protection element further includes a waste outlet located on the first conical portion.

20. The gas sensor of claim **19**, wherein the first axis extends through the waste outlet.

* * * * *